University of Maryland
National Study Center for Trauma and EMS

R Adams Cowley Shock Trauma Center

CIREN Program Report

Background

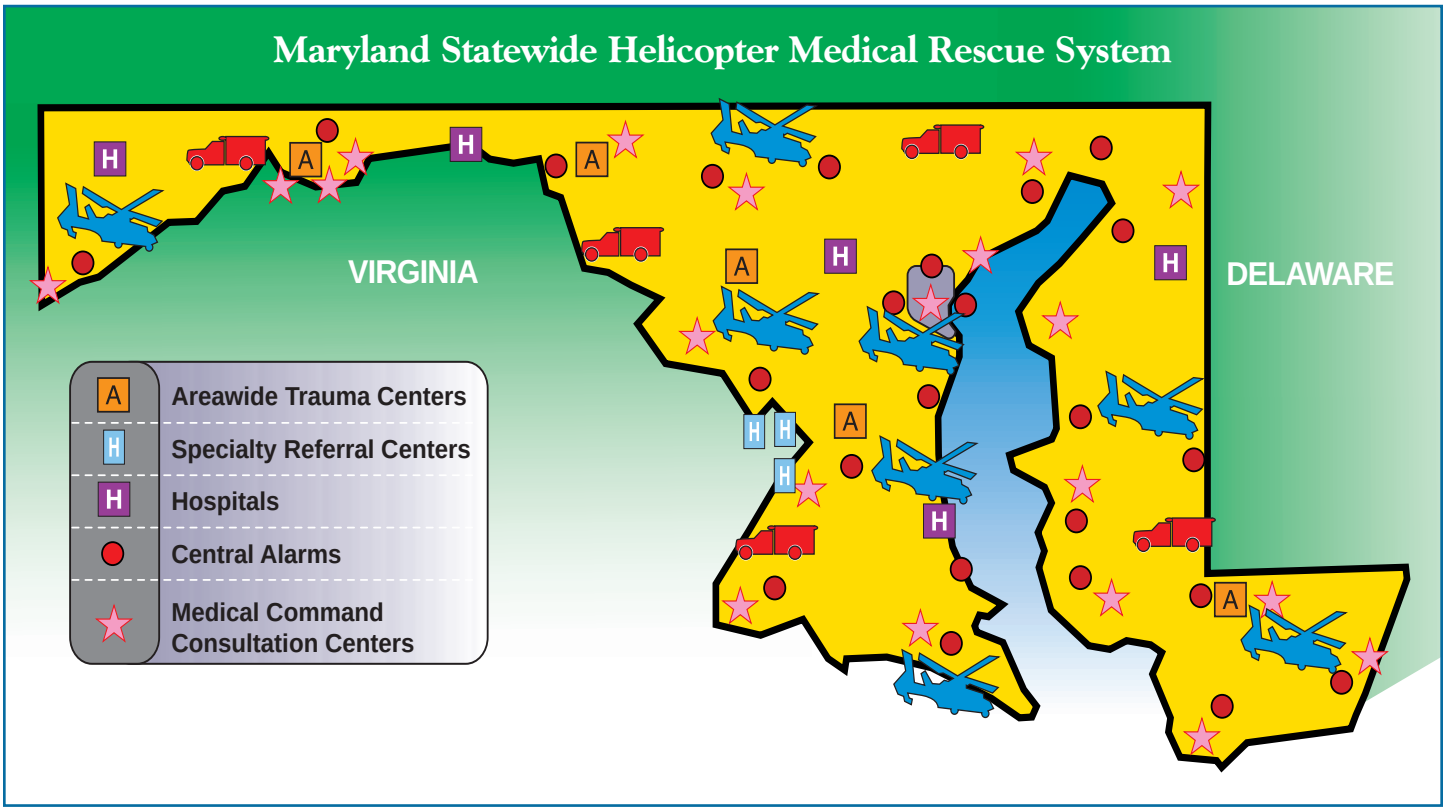
Clinicians and researchers at the National Study Center for Trauma and EMS (NSC) and the R Adams Cowley Shock Trauma Center at the University of Maryland, Baltimore have been investigating motor vehicle crashes and their associated injuries since the late 1980's. The roots of the Crash Injury and Engineering Network (CIREN) at the University of Maryland begin more than a decade ago with the original 'Motor Vehicle Crash Study' under the direction of Dr. John Siegel. Since then, more than 400 crash reconstructions have been performed by the University of Maryland and its partners, more than half as part of the CIREN program. By combining the detailed, multi-disciplinary approach of CIREN with our ongoing work on the epidemiology of motor-vehicle related injury, a clear picture of the causes, costs, and outcomes of these injuries may be obtained. Further, due to our unique statewide study area, the benefit and effectiveness of safety programs may be better quantified and the results serve as a model for other states and regions to implement.

Maryland was the first state in the country to establish a comprehensive, coordinated statewide system for the delivery of emergency health care services and is a recognized national leader in the field. Based on this recognition, the Charles McC. Mathias, Jr. National Study Center for Trauma and Emergency Medical Systems (NSC) was created in 1981 by a United States Senate Joint Resolution. The Center is to conduct trauma-related research with a focus on establishing national policies relating to prevention and treatment of injuries and their causes. The NSC is part of the University of Maryland School of Medicine and serves as the research arm of the Maryland Institute for Emergency Medical Services Systems (MIEMSS) and the R Adams Cowley Shock Trauma Center.

One goal of Maryland's EMS system is to transport patients to the most definitive level of care necessary for treatment of their illness or injury. A key component of this operation is the Med-Evac system which is operated by the Maryland State Police. Eight helicopters are stationed geographically throughout the state (see map below) and are manned by paramedic-certified state troopers. Over the past several years, the Med-Evac program has transported over 10,000 patients from the scene of a critical injury. A large percentage of these injuries result from motor vehicle crashes.

With 7,000 admissions annually, the R Adams Cowley Shock Trauma Center (STC) is the clinical hub of Maryland's system of emergency/ trauma care and thus serves injured citizens statewide. The STC has 24 Intensive Care (ICU), 24 intermediate/step-down, and 34 acute care beds, 10 trauma resuscitation bays, 6 ORs and 7 PACUs. As the lead hospital in Maryland's emergency medical system, the STC is committed to strengthening the total system of care in Maryland, improving clinical outcomes, and promoting injury prevention. The STC also serves as a national and international resource for the development and training of future leaders who will advance the development of trauma and emergency care systems.

In 2000, Maryland's population was 5,296,486, according to the Census Bureau. With 529.1 persons per square land mile, it ranks 6th in population density among the states. Maryland's comprehensive roadway system (29,072 miles) is maintained by the State Highway Administration and 24 political subdivisions and supports in excess of 48 billion annual vehicle miles traveled. There are approximately 3,500,000 licensed motor vehicle drivers and 3,700,000 registered vehicles in Maryland. Three-quarters of those



SYSCOM – the Statewide System Communication Center for Helicopter Medical Rescue

vehicles are passenger cars and 1.5% are motorcycles. Young drivers (ages 15-24) account for roughly 13% of the licensed population while older drivers (ages 65+) account for approximately 11%. While declining slightly since the early 1990's, Maryland's fatality rate has leveled off over the past several years at approximately 12 per 100,000 population (see figure 1). The state's mix of rural highways and urban arteries presents a unique challenge to highway safety and injury control planners, emergency medical providers and clinicians.

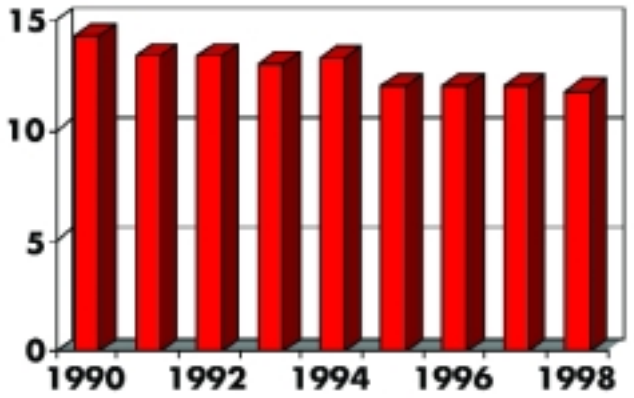
Maryland has a wealth of resources for the study of motor vehicle-related injuries. In addition to a centralized, coordinated EMS system, we have a centralized medical examiner's system, providing data on all vehicular fatalities in the state. From hospital discharge records, we also have access to data on all vehicle occupants who are either admitted to Maryland hospitals or treated in emergency departments and subsequently released. In addition, each of the nine trauma centers provides data to a statewide trauma registry. By comparing the select group of CIREN patients with the information from these larger data sources, it is possible to determine the representativeness of the CIREN population.

Joint and collaborative reviews with other CIREN centers

In an effort to interact and share expertise with other CIREN centers, Maryland CIREN staff have traveled in the past year to the Birmingham and Seattle Centers, where they participated in case reviews. Staff members from Michigan, New Jersey, Children's, Fairfax, and Birmingham have also participated in case reviews at the Study Center. Data from Maryland CIREN cases have also been compiled for use by other centers in the development of presentations and journal articles.

As one of the first CIREN centers, Maryland staff members provided considerable input into the development of the database, serving as one of the alpha test sites. In addition, we have had the opportunity to present the importance of the CIREN program to representatives from Ford and Daimler-Chrysler prior to their participation in the CIREN network.

Figure 1.
Maryland fatality rate per 100,000 population



Staff

One of the strengths of the Maryland CIREN Center is the multidisciplinary nature of the staff.

Patricia C. Dischinger, PhD, Principal Investigator, is an Associate Professor in the Department of Epidemiology at the University of Maryland School of Medicine. Dr. Dischinger has been a researcher at the NSC for 16 years. Much of her research has focused on motor vehicle-related injuries. She is also Principal Investigator for the NHTSA-funded Crash Outcome Data Evaluation System (CODES) project, which examines the epidemiology of motor vehicle-related injuries using available statewide databases, such as police crash reports, ambulance runsheets, and hospital discharge records.

Andrew R. Burgess, MD, Co-Principal Investigator, is Professor of Orthopaedics at the University of Maryland and The Johns Hopkins University and is a world-renowned orthopaedic surgeon with a particular interest in motor vehicle safety. Dr. Burgess has served as Co-Investigator for several transportation safety studies funded by the National Highway Traffic Safety Administration and the Centers for Disease Control in recent years. He regularly participates in case review meetings where he provides unique insight into injury mechanisms and their implications for long-term outcomes. A past president of the Orthopaedic Trauma Association, Dr. Burgess is particularly well known for his expertise in pelvic and leg injuries.

Timothy Kerns, MS, is a database engineer at the NSC and has served as the CIREN project coordinator since 1998.

Kathleen Read, MSW, is a Clinical Social Worker and outcomes researcher. She is responsible for interviewing patients using the SF-36 and other standardized testing instruments.

Shiu M. Ho, MS, has been employed as a data processing system analyst /database engineer for the Charles McC. Mathias, Jr., National Study Center for Trauma and EMS (NSC) since 1990. She is responsible for developing and implementing queries of the CIREN database.

Joseph A. Kufera, M.A., has been employed as a research statistician for the National Study Center since 1993. He is responsible for statistical analysis of the CIREN and outcome databases.

Nafeesa Jawed, MD, is a clinical research associate with the NSC and is responsible for screening and identifying eligible CIREN patients. She is also responsible for entering the medical and clinical variables into the database and for abstracting crash related autopsy reports.

Cynthia Burch recently joined the NSC after earning an MPH degree from the Medical College of Virginia. In addition to her work on other traffic safety projects underway at the NSC, she is responsible for the completeness and quality of the data entered into Baltimore's CIREN database and has been working closely with Dynamic Science and Indiana University.

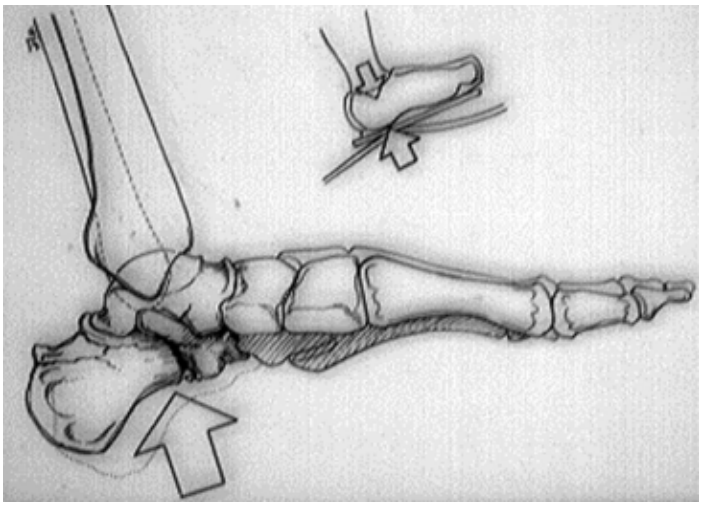
Debra Malone, MD, is the Director of Education and Research for the Coalition for Sustainment of Trauma and Readiness Skills at the trauma center. Dr. Malone frequently attends the case review meetings and contributes her expertise in chest and abdominal injury.

Dynamic Science, Inc., under the direction of Frances Bents, has performed the crash reconstructions for the Baltimore center since the original crash study. In addition to the reconstructions, Dynamic Science is responsible for the input of all crash data and photographs into the CIREN database.

In addition to researchers and physicians from the NSC and STC, our case review meetings are frequently attended by representatives from NHTSA-Washington, NHTSA-Region III, the Office of the Chief Medical Examiner of Maryland, the Maryland Highway Safety Office, and the Maryland State Police Crash Team.

Lower Extremity Injuries

A major focus of research at the Maryland Center has been that of lower extremity injury. These injuries are costly, frequently result in lifetime impairments, and are preventable. Although current information on the biomechanics of these injuries is still insufficient, it is known that they occur most often in frontal and offset frontal collisions, that seatbelts may be ineffective with respect to their prevention, and that vehicular intrusions of the toepan and instrument panel are often, but not always associated with their causation. Many collisions resulting in these injuries occur at delta v's well within the purview of current regulatory standards.



Among patients admitted to trauma centers following motor vehicle crashes, approximately 20% of drivers have at least one lower extremity fracture; the highest incidence rate for a specific fracture is for ankle injuries, with an incidence rate of 5.7%. Surveys suggest that foot and ankle injuries account for 8-12% of all moderate-to-serious injuries sustained by motor vehicle occupants involved in frontal collisions. In a study of the one-year treatment charges for persons hospitalized in Maryland with motor vehicle-related injuries, lower extremity injuries accounted for 40% of the total.

Lower extremity injuries from car crashes tend to be high-energy injuries, which have a poorer prognosis than comparable low-energy injuries caused by slips and falls. Because they involve weight-bearing surfaces and joints, knee and ankle fractures often result in prolonged reductions in mobility. Proximal foot fractures (talus, calcaneus) involve the complex, weight-bearing joints of the ankle and hindfoot and may also result in long-term impairment and disability. However, the disabling nature of these injuries is not reflected by their low scores on injury severity scales which are usually designed to reflect threat to life and not to predict nonfatal outcomes. By collaborating with engineering colleagues at the University of Virginia Auto Safety Lab, we have been able to "recreate" some of these injuries, using experimental techniques such as computer modeling. Also, based on epidemiologic evidence, we were able to show that women had a higher incidence of ankle/foot fracture than did men, and that this was probably a function of driver height. Ankle and foot fractures, which are especially disabling injuries with long-term consequences, frequently result from a combination of axial loading and inversion/eversion forces and are often accompanied by intrusion of the toepan.

With increasing survival rates among drivers in high-speed crashes, due to availability of both seatbelts and airbags, it is anticipated that there will be a relative increase in serious lower extremity injuries among people who would have previously died of multiple trauma, including head, thorax, abdominal, and lower extremity injuries. From in-depth crash reconstruction studies, it is possible to learn more about the mechanism of these injuries, and thus, working with biomechanics experts, address scientific strategies for prevention. As safety equipment and vehicle designs change over time, it will be possible to monitor these changes and their effects on lower extremity injuries, which are currently, with the exception of femur fractures, not influenced by seatbelt use or airbag availability.

Perhaps the value of CIREN is best exemplified by the combination of insight provided by epidemiologists analyzing the incidence of motor vehicle related injuries, surgeons responding with acute and follow-up treatment of those injuries, and social scientists investigating the long-term physical, financial, and psychosocial effects of such injuries.

Long-term consequences of motor vehicle crash injuries

Long-term consequences of motor vehicle crashes include data not only on physical outcomes and functioning, but also the impact of the trauma on the family and society as well as the psychological changes following injury. An important aspect of our research is the in-hospital interview (conducted by our CIREN social worker), and follow-up interviews obtained at 6 and 12 months following hospital discharge. Although the data obtained on the acute injury provides important information about the mechanism of injury, forces, and contact points which resulted in the injury, the true impact of the injury on the trauma patient (both physical and psychosocial) can only be understood from long-term outcome research. NSC staff has donated its expertise in interacting with some of the other centers with regard to the collection and analysis of follow-up data on the human consequences of crash injuries.

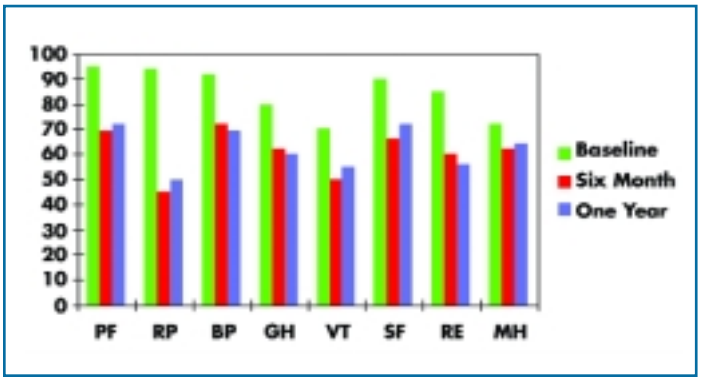
Learning about the survivors of trauma and understanding what happens to the people involved in motor vehicle crashes provides an opportunity for injury prevention professionals to partner with survivors and families. Their stories provide an important link to understanding and achiev-

ing prevention goals. Physical and or psychological impairments resulting from trauma often take years to overcome. Psychosocial information provides the human dimension of real world crashes when a person is confronted with sudden death, severe injury, and loss. The impact of trauma extends well beyond the crash for the patient, family and society. Since many injuries are costly and disabling, patients often must build a 'bridge' between their pre-crash and post-crash lives. Now, with the increasing availability of airbag restraint systems, more vehicle occupants are able to survive serious crashes. However, many whose lives have been saved are still left with residual injuries.

In Maryland, an in-depth interview with the patient and or family is conducted in the trauma center to establish a pre-injury baseline and history which includes information about their occupation and job, insurance, co-morbidity factors, behavior and risk taking characteristics, the role of alcohol and drugs as well as acute care, rehabilitation and other costs. In addition to an interview, several standardized measurements are utilized, including the SF36 (Short Form Health Survey). Patients are again interviewed at six and twelve months to determine the long term consequences of their injuries. To date, 260 interviews have been conducted.

Below is a graph depicting results of the SF36, which is a health assessment measurement tool that includes one multi-item scale that assesses the following eight health concepts:

1) Physical Functioning (PF): measures limitations in physical activities from bathing and dressing to rigorous activity;
2) Role-Physical(RP): measures physical problems in performing work related activity;
3) Bodily Pain(BP): measures absence of pain;
4) General Health(GH): measures one's beliefs about personal health status;
5) Vitality(VT):measures degree of energy and fatigue;
6) Social Functioning(SF): measures the extent physical or emotional health interferes with social activity;
7) Role-Emotional(RE): measures the extent emotional health interferes with work or daily activity; and
8) Mental Health(MH): measures psychological distress and well-being.



The scale above clearly shows that the CIREN patients demonstrate functional limitations at six and twelve months post-trauma, and that, on average, they have not returned to their pre-injury level of functioning.

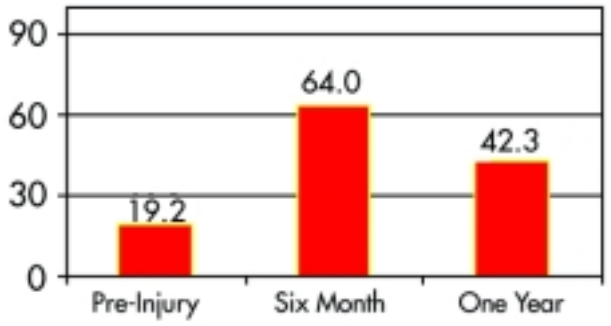
Due to the limitations of the SF36, it is necessary to supplement this tool with other forms of measurement and we have included separate questions in an effort to analyze cognitive function. Unfortunately, there is not one model that exists to assess all the psychosocial outcomes of injury, but clinical experience and methods suggest that many factors are important influences in outcome. Some of the factors considered in our research include pre-existing conditions, socio-economic factors, substance use, depression, post-traumatic stress disorder (PTSD), and litigation. It is also necessary to look at specific groups, for example those with lower extremity injuries, where the long-term consequences may be more costly and disabling. One of the major potential consequences of motor vehicle crashes is the development of post traumatic stress disorder (PTSD). More than 38% of CIREN patients with a lower extremity injury exhibited symptoms consistent with PTSD (see Figure 2).

Figure 2.
Psychosocial Outcomes for Lower Extremity Injury

	Six Month	One Year
	%	%
Behavioral Problem	50.0	23.1
Cognitive Problem	38.5	30.8
Pain Issues	76.9	61.5
Litigation	73.1	46.2
Return to Driving	73.1	88.5
Life Altering Experience	69.2	80.8
Post-traumatic Stress	46.2	38.5

The ways in which people experience a traumatic event and how they are affected by that event varies by individual. There is a range of frequently occurring reactions, most commonly involving physical reactions (nervousness, sleep difficulties, fatigue etc.); mental reactions (fearfulness, loss of control, poor attention, intrusive images etc.); emotional reactions (sadness, grief, guilt, feeling helpless); and behavioral reactions (avoidance, withdrawal, increased irritability, etc.). These reactions depend on one's perception of the loss or threatened loss, physical progress following injury, the fear or horror experienced, the degree that patients hold themselves responsible, prior losses and traumas, current life stressors, and coping patterns. Prior medical and psychosocial history may influence long-term

Figure 3.
Depression/Anxiety



outcomes and psychological well-being. Figure 3 depicts the rates of depression, both pre- and post-crash, among patients with a lower extremity injury. The more we know about such long term outcomes of motor vehicle crashes, the more we learn about how to provide effective treatment programs.

Summary

With the increasing availability of modern occupant restraints including airbags and seatbelts, more drivers survive serious collisions. Thus, it becomes more important to consider the long-term outcomes of these injuries in order to set priorities for injury prevention as in the Haddon Matrix. Lower extremity injuries provide a useful model for this concept as they are usually not life threatening but may have major implications with regard to long-term functioning. Since these injuries occur despite available occupant restraints, new technological advances must be provided in order to prevent these disabling and costly injuries.

Relevant Publications

Brennan P, Dischinger P, Ho S, Kerns T. "Motor vehicle airbags and injury. The Maryland experience." Presented at the 1996 meeting of the Third International Conference on Injury Prevention and Control (Poster).

Crandall JR, Martin PG, Bass CR, Pilkey WD, Dischinger PC, Burgess AR, O'Quinn TD, Schmidhauser CB. "Foot and ankle injury: The roles of driver anthropometry, footwear and pedal control." *40th Proceedings of the Association for the Advancement of Automotive Medicine*, pp 1-18, 1996.

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Dischinger PC, Burgess AR, Cushing BM, O'Quinn TD, Schmidhauser CB, Ho SM, Juliano PJ, Bents FD. "Lower extremity trauma in vehicular front-seat occupants: Patients admitted to a Level 1 trauma center." In: *In-Depth Accident Investigation: Trauma Team Findings in Late Model Vehicle Collisions*, Warrendale, Society of Automotive Engineers, Inc, 1994, pp 11-18.

Dischinger PC, Burgess AR, Cushing BM, Pilkey WD, Crandall JR, Sieveka EM, Klopp GS. "Lower extremity trauma in vehicular front-seat occupants." In: Shieh SJ (ed), *Proceedings of the Injury Prevention through Biomechanics Symposium*, Michigan, Centers for Disease Control, Wayne State University, 1994, pp 29-42.

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Presentations

In addition to the annual and quarterly CIREN meetings, the staff of Maryland's CIREN center has been very active in promoting CIREN activities on both a national and local level. Dr. Burgess, in particular, has made numerous presentations to a variety of groups and organizations. The following list is a sample of presentations made by CIREN staff over the past several years.

"Airbags: new dynamics and what they mean to the orthopaedic surgeon." Grand Rounds, Department of Orthopaedic Surgery, The Johns Hopkins Hospital (Baltimore, MD; 2/5/98)

"Motor vehicle crash research (CIREN): airbags and lower extremity injuries." Volunteer Fire Department Convention (White Marsh, MD; 2/25/98)

"Airbags, lower extremity injuries and crash reconstruction." EMS Care '98 (Towson, MD; 5/30/98)

"Crash reconstruction the CIREN experience." Grand Rounds, R Adams Cowley Shock Trauma Center (Baltimore, MD: 10/2/98)

"Airbags – lower extremity injuries (CIREN)." State Farm Insurance Claims Adjusters Meeting (Columbia, MD; 11/19/98)

"Psychosocial characteristics and risk-taking behaviors." Society for Social Work and Research – University of Texas. (Austin, TX; 1/99)

"What we have learned from CIREN crash data." AO North American Visiting Professor. Harborview Medical Center, University of Washington (Seattle, WA: 7/23/99)

"Advanced crash studies, what we have learned from CIREN: relevance to prehospital providers." Western Maryland Trauma Days, Garrett Community College at McHenry (Garrett County, MD; 11/7/99)

"Airbag associated injury patterns." 18th R Adams Cowley National Trauma Symposium (Baltimore, MD; 11/18/99)

"Special Needs of Families of Trauma Victims." American Trauma Society Annual Meeting. (Arlington, VA; 1/00)

"Prehospital providers and mechanism of injury." Kingsville Voluntter Fire Department (Kingsville, MD; 2/5/00)

"Mechanisms of musculoskeletal injury in MVC." Current Controversies and Trends in Orthopaedic Trauma Management (Tucson, AZ; 3/4/00)

"Shock and trauma emergency services and systems for saving lives." Future Urban Transport: Problems and Solutions Interactive Conference (Goteberg, Sweden; 3/30/00)

"Auto crashes and airbags – what we have learned." National Association of Orthopaedic Nurses Conference (Baltimore, MD; 4/12/00)

"CIREN crash reconstruction." EMS Care 2000 (Timonium, MD: 4/30/00)

"CIREN Overview." Special Topics in Trauma Nursing. University of MD School of Nursing (Baltimore, MD 10/00)

"Automotive crashes and the orthopaedic surgeon." Visiting Professor. Case Western Reserve, MetroHealth Medical Center (Cleveland, OH; 11/3/00)

"Clinical and biomechanical aspects of lower extremity injuries, The CIREN Project." 44th Annual STAPP Car Crash Conference (Atlanta, GA); 11/5/00)

"Car crashes: effects on your practice." Visiting Professor. 33rd Annual Peter H. Mack Memorial Lecture, Johns Hopkins University (Baltimore, MD: 11/17/00)

"Blunt cardiac trauma in a restrained driver with an air bag." National Highway Traffic Safety Administration CIREN Public Meeting (Washington, DC; 11/30/00)

"Automobile crashes airbags, and lower extremity injury – what have we learned from the CIREN experience?" Annual George H. Greenstein, MD Lecture, Northwest Medical Center (Randallstown, MD: 12/6/00)

"A multidisciplinary approach to car crash research." University of Maryland School of Social Work. (Baltimore, MD; 12/00)

"Motor vehicle crashes and musculoskeletal injury – effects on the practice of emergency medicine." Emergency Medical Conference, R Adams Cowley Shock Trauma Center (Baltimore, MD; 1/24/01)

"Aging and Driving. Psychosocial Factors and Injury Outcomes of Motor Vehicle Occupants Over 60." AAAM (Detroit, MI; 2/01)

"Clinical lessons learned from CIREN motor vehicle crash reconstruction." Surgical Grand Rounds, Morristown Memorial Hospital (Morristown, NJ; 3/14/01)

"Auto safety – is it really safe to drive?" The CIREN Project. State of the Art in Orthopaedics 2001 (Whistler, British Columbia, CN; 3/20/01)

"Crash reconstruction: lessons for the orthopaedic surgeon from CIREN." Visiting Professor. Louisiana State University (New Orleans, LA; 6/23/01)

"Vehicular crashes – how to keep our patients safe." 2001 Orthopaedic Nursing Update Meeting (Baltimore, MD; 7/20/01)